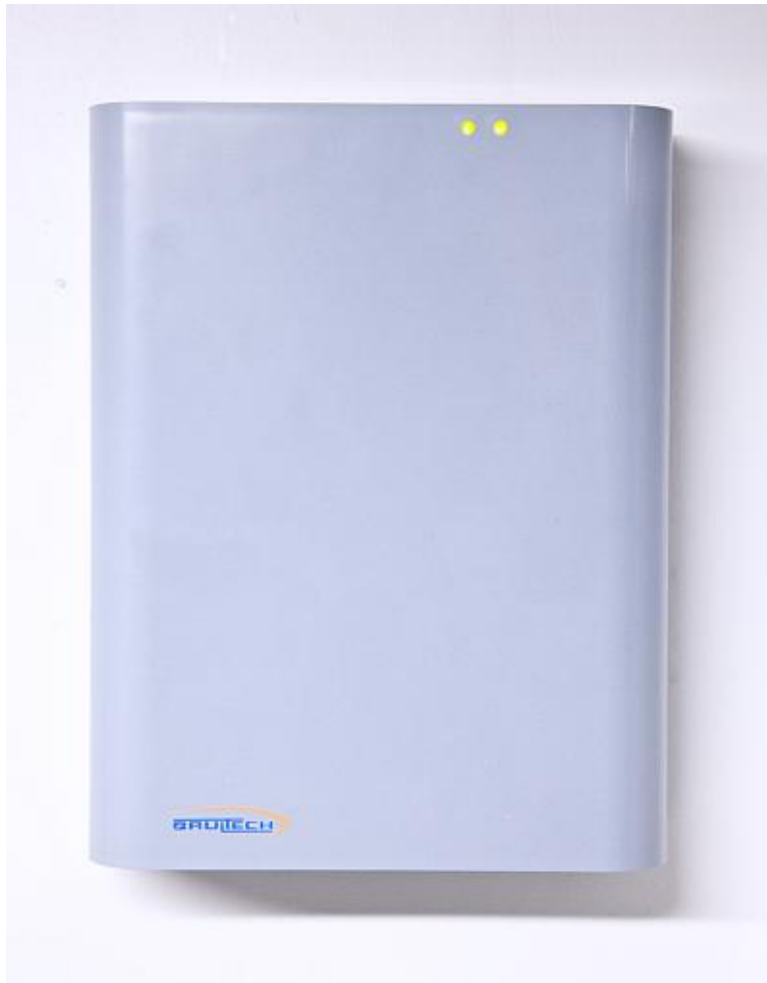# GreenEye Monitor™ Manual

(*Preliminary/Incomplete*)



## Energy Consumption Monitor
**With Pulse Counter and Temperature Sensing Inputs**

# Introduction

The GREENEYE MONITOR (GEM) Home Energy Monitor is a multi-channel power meter designed to measure the consumption of residential service panels and/or panel circuits. The measured data is then transferred to a computer or internet server for storage, analysis and real-time display.

The primary function of the GEM is to monitor electrical energy consumed. Additional inputs have been included to measure other consumables such as water, gas and propane, providing there is a pulse signal available from such devices. The GEM also provides a "1-Wire Bus" which accepts low cost sensors to monitor temperature from various rooms and outdoors.

The GEM processes all of the measured data then sends it to a host computer, server or website for display and analysis.

## Overview

The basic function of the GEM is to:

1.  Read and convert the sensor signals to real-world values.
2.  Process the acquired metrics.
3.  Forward the data to a host for access via computer, internet, automation system or smart phone.
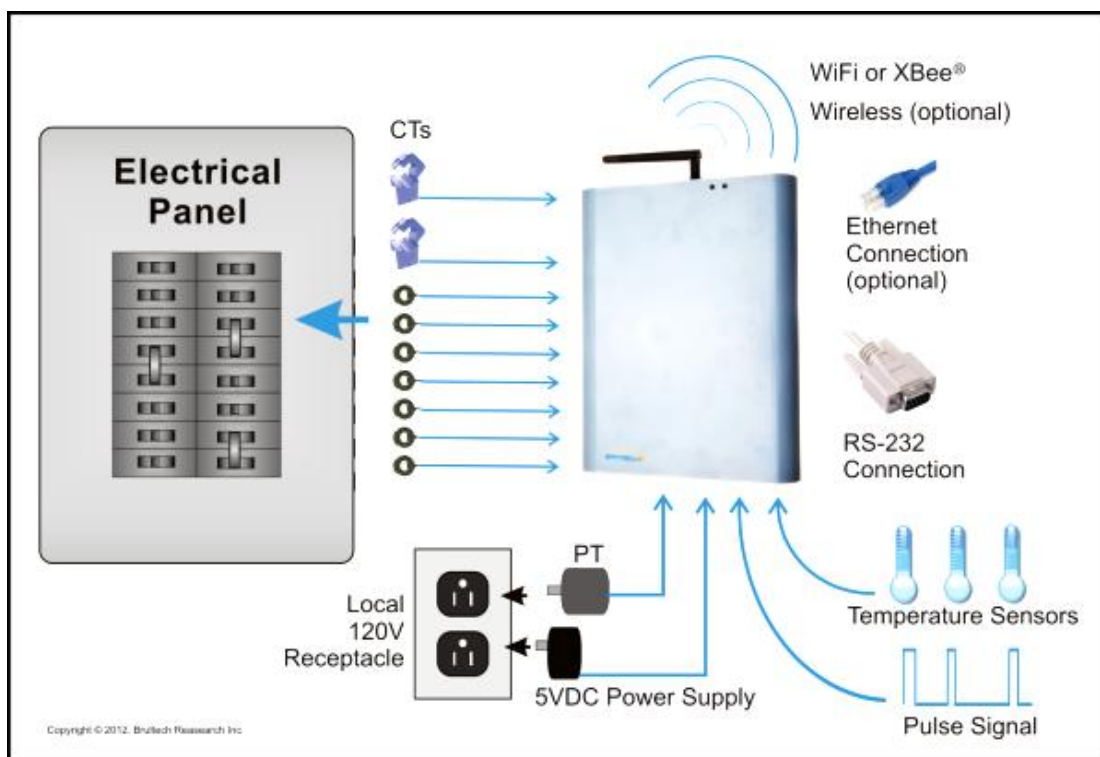


**NOTE:** *Only low voltage, galvanic isolated signals are connected to the GreenEye™ Monitor!*

The current sensors (CT) are small non obtrusive devices installed in the electrical panel on each circuit breaker circuit. Two larger CTs are installed on the power feed from the Utility Company, providing total house consumption. Optionally, other sensors may be connected to provide temperature or water/gas consumption.

Two supplies are used, one +5V supply to power the GEM and the second to monitor the power line voltage for accurate true power conversion.

The GEM converts the data from the sensors and makes it available to a host. The host could be one or more of the following:

- A website dedicated to monitoring, displaying and charting consumption information.
- A local web server. We have available, a small powerful web server which consumes less than 5Watt to operate (That's less than 2 cents per day)
- Personal website.
- Local PC
- Home automation system
- Smart phone via one of the above options
- Your own custom solution. We provide API information upon request.

There is a variety of options available for communication depending on the server option chosen and wireless range. The communication options are:

- Two RS-232 COM ports via push terminal block
- Wifi communication (optional)
- Ethernet connection (optional)
- XBee® Module for ZigBee® communication (optional)

## The sensors

Various sensors may be used with the GEM:

- Current Sensors
- Voltage Sensor
- Pulse Output Devices
- Temperature Sensors

### *Current Sensors*

Current sensing is done using **"current transformers"** referred to as **"CT"** throughout this manual. The CTs we use require no electrical connection since the sensed electrical current is accomplished by reading the magnetic field of an electrical conductor.
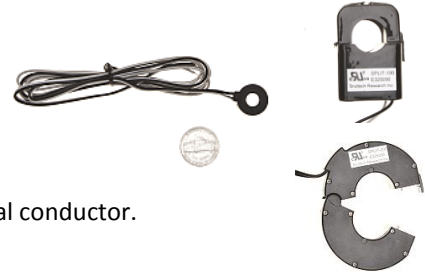
### *Voltage Sensors*

The powerline voltage needs to be measured in order to calculate "true power". This is accomplished using a single **"potential transformer" referred to as "PT"** throughout this manual. The "powerline voltage" is the voltage present at the electrical receptacle, typically 120V or 240V depending on the Country. The PT isolates this voltage and reduces it to a safe low voltage value for the GEM to monitor.

### *Pulse Output Devices*

Some water, gas and propane meters provide a "pulse output". This is a simply ON-OFF signal which occurs any time an "*x*" amount of a given consumable is used. For example a water meter could provide a single on-off pulse for each gallon used. These pulses are accumulated by the GEM to provide the amount and time of consumption. If the meter does not provide a pulse signal then one can be added to existing water, gas or other system. *(Check with local utility company for rules and codes!)*

The picture on the right shows a typical water meter with pulse output available from http://www.temcocontrols.com

### *Temperature Sensors*

The GEM uses a "1-Wire®" bus for temperature sensing and is based on the Maxim/Dallas DS18B20 sensors. These sensors can share a common 3-conductor cable.

The picture on the right shows a typical temperature sensor available from http://www.adafruit.com

## Communication

The GEM offers a multitude of communication options to transfer the monitored data to its destination. Two separate ports each providing various communication options are provided:

1. RS-232
2. WiFi (optional) *will soon be discontinued due to erratic performance of Roving Networks' RN-171 WiFly Module.
3. Ethernet (optional)
4. Combination WiFi and Ethernet module (optional) *recommended
5. ZigBee® via XBee® modules from Digi.com (optional)
6. A PCB header for custom options

# Where to Start

It is very important to **plan** the installation of the GreenEye Monitor (GEM). The guide below will help ensure a smooth installation.

## Read and UNDERSTAND the safety information

This is the most important step! Not only will this help ensure that the installation will be according to local codes, but will also prevent injury, fire or fatality.

## Power up and establish communication before installing

This mainly applies to systems using WiFi or ZigBee® wireless communication. It is recommended to simply power up the GEM (without any sensors connected) while in close range to the WiFi router or ZigBee® coordinator whichever applies, and configure the SSID, IP address, etc. This will help decipher any possible range issues if there are problems with the wireless connection.

## Plan the mounting location for the monitor, taking into consideration the CT lead length

It is important to consider where the CT leads will be routed when choosing a location to mount the GEM. If mounted to far away, the CT leads may not reach the terminal strips. The best location is usually as shown in the pictures below:

1.



SPLIT-200 CTs have longer leads than Micro CTs

SPLIT-200 CTs have longer leads than Micro CTs
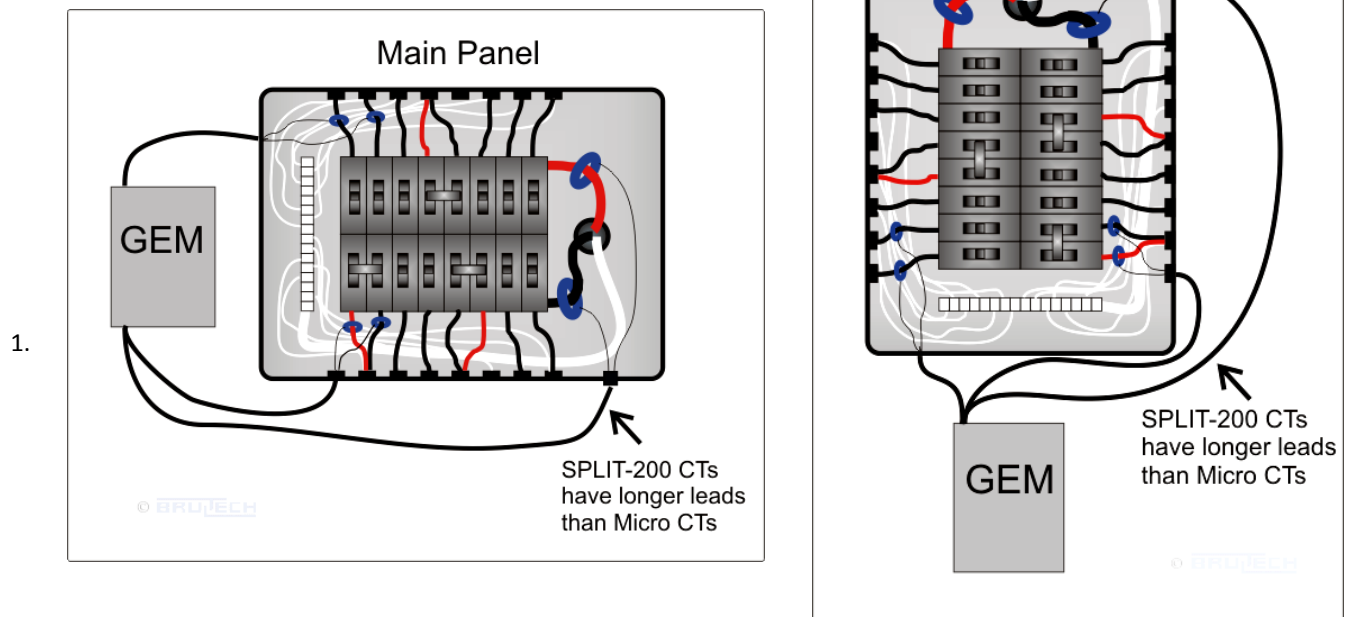
Identify the mounting area for the GREENEYE MONITOR (GEM)

Identify the breaker panel circuits you will be monitoring. Occasionally, circuit breakers are improperly identified. Switch the breaker off to verify that it indeed kills the power to the load in question.

⚠ **WARNING !**

**NEVER Install The GREENEYE MONITOR (GEM) Unit Inside the Electrical Panel**

Any GREENEYE MONITOR (GEM) input which will host more than one CT requires special attention so that the CT is installed with proper orientation. This is explained later in this chapter.

The diagram below illustrates a very simple installation. Typically, the installation will involve using more current sensors to measure as many electrical loads as possible.

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# Important Safety Information

The GREENEYE MONITOR (GEM) operates as a "Class II" low voltage device. This requires that all external connected signals be a low voltage (<50V) and provided by Class II approved power supply and sensors.

All of our power supplies are UL, CSA or UL/c approved for use in USA and Canada. Most of our current transformers (CT) are UL/c listed. No direct line connections to the GEM are allowed. All signals must be galvanic isolated from the power-line.

⚠️ **WARNING !**

**Read All Of The Safety Rules Before Installing!**

Never install the GEM inside an electrical panel. A separate "low voltage" panel may be used when needed.

The GREENEYE MONITOR (GEM) installation requires the installation of current transformers (CT) installed inside the electrical service panel. This portion of the installation MUST be performed by a qualified electrician or individual. The installer must follow all local safety codes and use proper safety practices and equipment.

The qualified installer must be aware that main panels may still contain dangerous voltage levels even though the main breaker is in the "OFF" position.

**The following rules MUST be obeyed!**

- **Any work performed inside the electrical panel must be done by an electrician or qualified individual. This individual will be familiar with the local electrical code and perform the installation accordingly.**
- **NEVER install the GreenEye Monitor (GEM) inside the electrical panel. Only low voltage (12VAC or less) galvanic isolated connections are to be made to the GREENEYE MONITOR (GEM) terminals.**
- **The current transformer (CT) leads must exit the electrical panel through an appropriate box connector, strain relief or bushing. The CT leads must be properly anchored on the outside of the panel.**
- **The portion of the CT leads inside the panel must not have any damage, cuts or wear to the outside insulation.**
- **The CT leads must be routed in such a way that its insulation will not be rubbing against live terminals. Care must be exercised not to pinch the CT leads especially when re-installing the panel cover.**
- **Do not install the CTs in panels with voltages greater than 300V.**
- **Do not install the GREENEYE MONITOR (GEM) in a wet location.**

# Compliance

The GreenEye Monitor models GEM-W and GEM-E have been Tested to Comply with FCC Standards For Home and Office Use.

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:

(1) this device may not cause harmful interference, and
(2) this device must accept any interference received, including interference that may cause undesired operation.

**Wireless Versions:**

Contains FCC ID: OUR-XBEE2  (USA) (Wireless Versions Only)
Contains Model XBee® ZNet 2.5 Radio, IC: 4214A-XBEE2  (Canada)
May Contain Roving Networks WiFly Module FCC ID: T9J-RN171
May Contain FCC ID: AZYHF-A111

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# Overview / Layout

The diagram below illustrates various items and sections of the GEM circuit board. This chapter describes each numbered section.
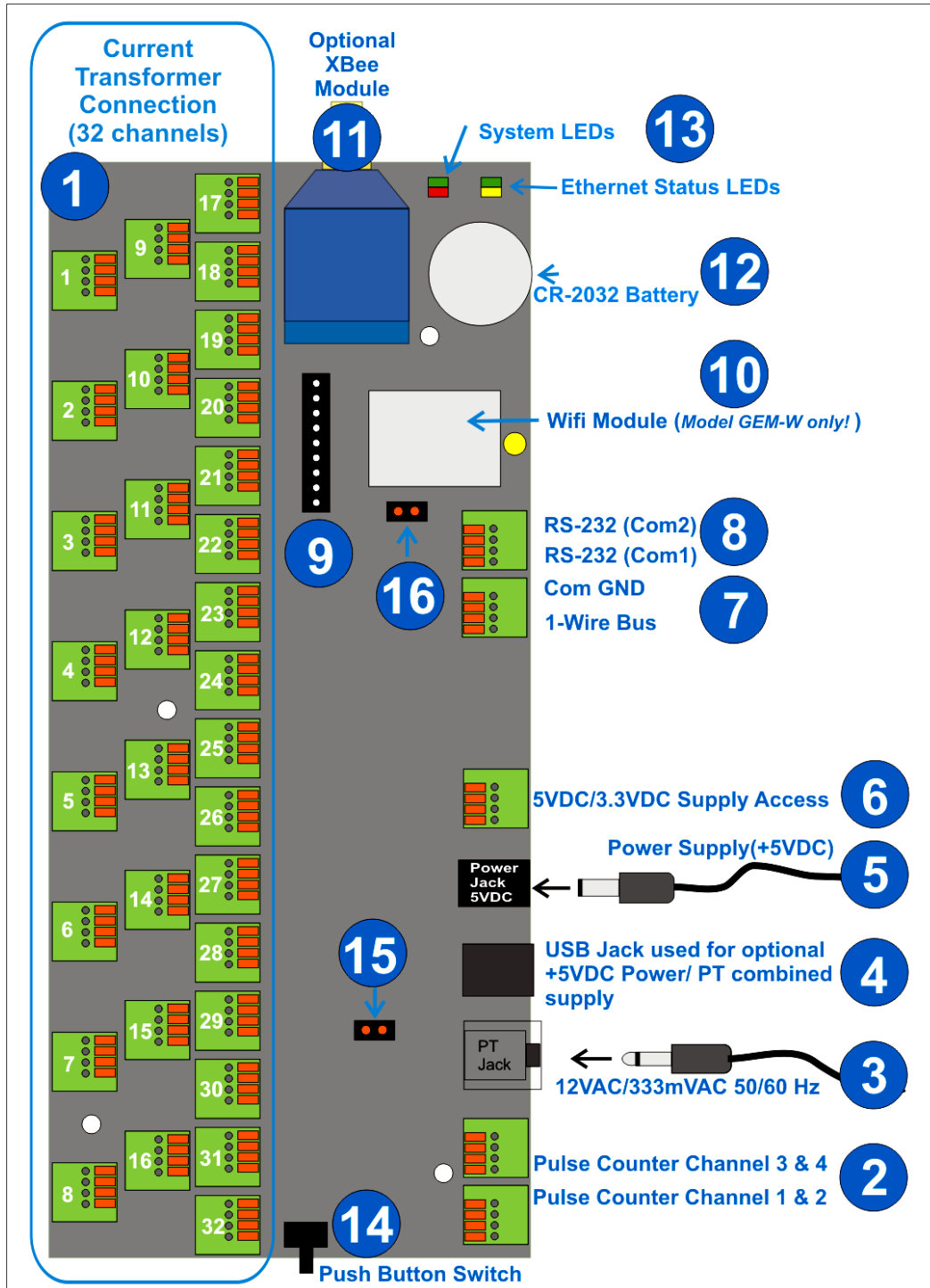
# (1) CT Connection Terminals

This section is composed of 32 terminal blocks, one for each of the power monitoring channels. The channel number is printed on the circuit board.

The terminal blocks have four terminals each. This is where the CT leads connect to the GEM

The terminals are numbered 1-4, although not marked directly on the terminal block. The legend below should be used as a guide.
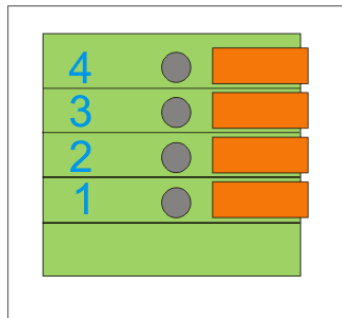
The terminal number to be used will vary based on the "Type" of the CT and the number of CTs connected to a given channel.
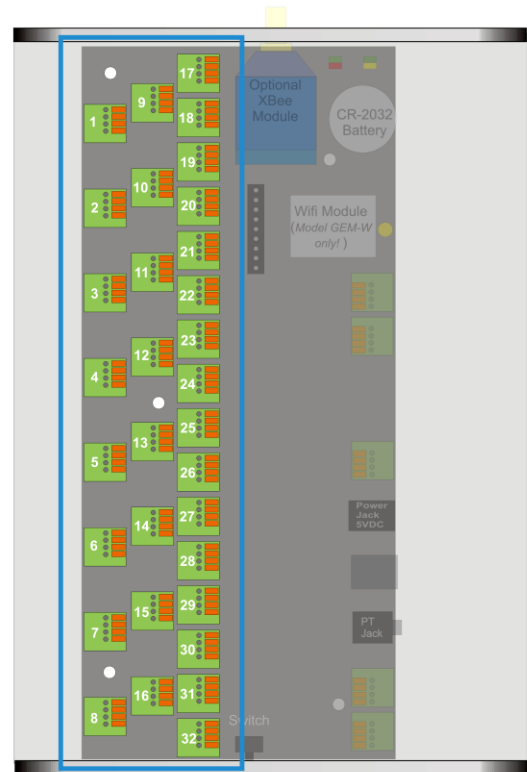
IMPORTANT! The CT leads must be stripped back 10mm for proper connection to the terminal block. See "Connecting CT to the terminal blocks" section.

# (2) Pulse Counter Inputs

The GEM has four pulse counting inputs. Pulse signals may be acquired from certain water, gas or electric meters to indicate the amount of consumption.

Pulse channels 1 and 2 are designed to accept voltage pulses and channels 3 and 4 are pulsed using "dry" contact closure.

See "Pulse Counting" section.

## (3) Potential Transformer (PT) Input

The GEM may receive the PT signal from the 3.5mm phone jack (#3) or via the mini USB connector (#4). The 3.5mm jack is a stereo style jack providing two voltage range options, depending on the PT used. See "PT" section for more information.

## (4) Alternate Potential Transformer (PT) And 5VDC Supply Input

**NOTE:** This is not a standard USB port for communication.

This mini USB jack may be used as an alternative to the 3.5mm jack (#3), providing the PT signal is in the 333mVAC (.333V) range. This USB jack us dual duty and may also provide an alternative to the +5 Volt DC power supply jack (#5).

## (5) GEM Power Supply Input

This 2.1mm X 5.5mm barrel jack is for the 5VDC supply connection. The center pin is the (+) positive connection.

## (6) Power Supply Access Terminals

This four terminal block provides access to the GEM's +5V and +3.3V supply. This is reserved for future options and special applications.

## (7) "1-Wire" Bus and RS-232 Ground Terminal

This four terminal block possessed the three connections for the "1-Wire" bus and also the "Common Ground" connection for the RS-232 connection (#8).

## (8) RS-232 Connection

This four terminal block encompasses the receive (RX) and transmit (TX) lines for both RS-232 COM ports.

## (9) Optional COM Module Header

This 10-pin 2mm pitch header provides access to the UART and power supply providing an interface for alternate communication modules. This header should only be used with available modules. Please contact Brultech if you wish to design a custom communication interface using this header.

## (10) Optional WiFi Module

The model "GEM-W" includes a WiFi communication module.

## (11) XBee® Module Socket

The GEM may be fitted with Digi's XBee® or XBee®-Pro modules providing ZigBee® communications. An opening is also included in the enclosure in should a module with external antenna is used.

## (12) Battery Holder

A CR-2032 battery is used to retain data under power outage conditions.

## (13) System and Communication LEDs

The left tri-color LED is used for "System Status".
The two color LED on the right side provides Wifi status if this option is present or other status depending on the Ethernet option included.

## (14) Push Button Switch

The push button switch stem is accessible from outside the enclosure. The purpose of this switch is to provide some optional settings when a communication link is not yet configured or available.

This switch is also used for exiting bridge mode. Anytime the communication is put into bridge mode which couples Com1 communication to Com2, any press of the switch causes the GEM to exit bridge mode.

The switch is also used to recover from situations where communication is lost while upgrading the "COM" processor's firmware thereby corruption the firmware. The push button switch is then pressed while power to the GEM is cycle allowing a fresh start to upgrading the firmware. Please follow the appropriate instructions with the setup program before attempting this.

There are two set of three functions available. Each set is entered using a specific key sequence. Once the sequence has been executed and the push button has been released, the "system" LED will generate the following sequence:

- Flash RED three times (function 1 option), then
- Flash GREEN three times (function 2 option), then
- Flash YELLOW three times (function 3 option), then exit the sequence and return to normal operating mode.

If the switch is briefly pressed during any of the flashing sequences, the option relating to the corresponding color will execute. For example, if the switch is momentarily pressed during the "green" sequence, the GEM will execute the "green option".

As mentioned before, there are two set of functions. Each set is entered by executing a unique key sequence.

The WiFi function is entered by pressing the switch and holding in ON for 6 seconds. Once the switch is released, the LEDs will perform the flash sequence as detailed above; green, red and yellow each flash three times in a row.

---

|  | **Options 1** | **Options 2** |  |
|---|---|---|---|
| **Push Button Sequence Required to Enter Option** | Press PB switch for 5 seconds then release | Press PB briefly four times in a row at 1 seconds intervals. (The red LED should come on each press) |  |
| **System LED Flash Sequence** | <ul><li>Red three times</li><li>Green three times</li><li>Yellow three times</li><li>Return to normal operation</li></ul> | <ul><li>Red three times</li><li>Green three times</li><li>Yellow three times</li><li>Return to normal operation</li></ul> |  |
| **FUNCTION if PB pressed while flashing:** |  |  |  |
| **Red** | WiFi Adhoc Mode for initial setup | Not yet defined |  |
| **Green** | Recall "user2" Settings | Send AT command to XBee® Module to search for ZigBee® PAN. (ATNR0) |  |
| **Yellow** | Recall "user3" Settings | Send "reset" (reboot) to WiFi and XBee® modules. |  |
| **FUNCTION if PB is NOT pressed during the flashing sequence** | Return to normal operation | Return to normal operation |  |

# Current Transformer (CT) Installation

## Important

The current transformers are installed inside the electrical panel. The CTs MUST be installed by a qualified individual. Read the "Safety" section at the beginning of this document!

CT Connection to the Terminal Strip

**NOTE: The CT leads must be stripped approximately 10mm (0.4") and have a gauge size between 18 and 26 AWG.**



The GEM uses spring loaded terminal blocks. The CT leads must be stripped the proper length. If the leads have stranded wire, it is preferable to "tin" the wire before hand to prevent dealing with frayed ends. *(Tinning is the process of adding solder to bond all of the strands together)*.
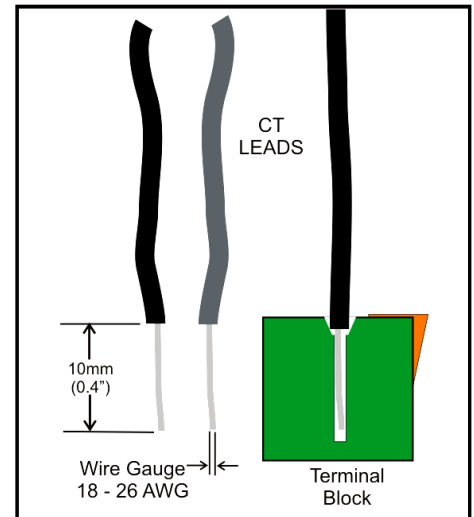
**Connecting the CT leads to the terminal strip**



1. Align the two lead ends with the terminal holes. This can be done one lead at a time, however its seems to be easier inserting both leads at the same time, providing they are nicely tinned with no frayed ends.
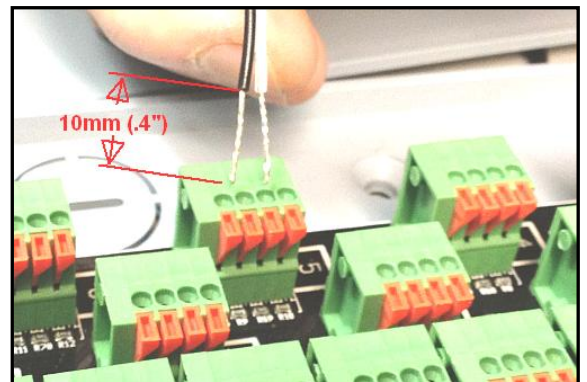
2. Press down on the orange TAB(s) corresponding to the lead or leads to be inserted, using a small "flat blade" screwdriver.
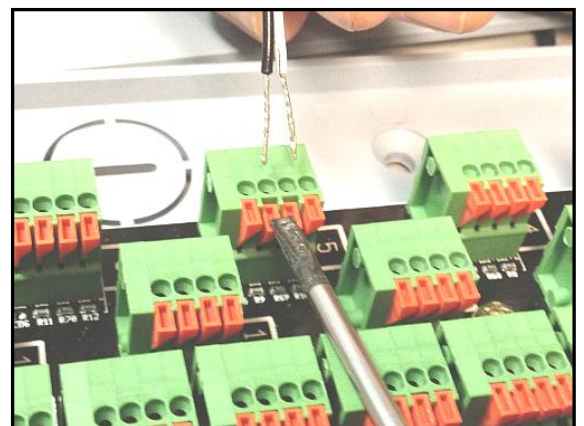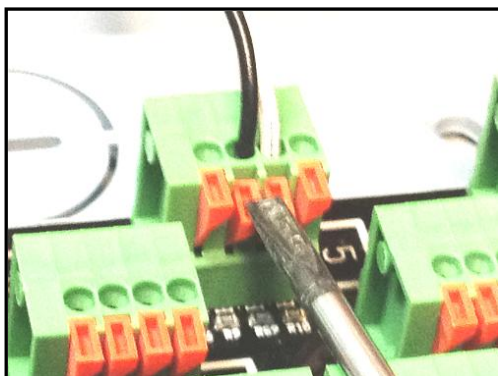
3. Insert the leads into the terminal block while making sure the leads are perpendicular. In most cases, both CT leads can be inserted at the same time. If the lead was stripped back 10mm, then the stripped section should be entirely inside the block with only the insulation visible.

4. Release the pressure to the spring tab.

5. Finally, tug slightly on the leads to make sure they are secure.

The channel number for each block is printed on the circuit board next to each terminal block as shown in the picture (right).

# IMPORTANT!

**Two types of current transformers are compatible with the GEM, Types A and B.**
The difference between each type has to do with the type of signal which represents the sensed current:

**TYPE A:** The measured current is represented by a <u>voltage</u> output signal.
**(SPLIT-60, SPLIT-100, SPLIT-200, SPLIT-400)**

**TYPE B:** The measured current is represented by a <u>current</u> output signal.
**(Micro-40, Micro-80, Micro-100, SPLIT-170)**

Because of this difference, each CT type has to be connected to the terminal strip of the GEM in a different manner.
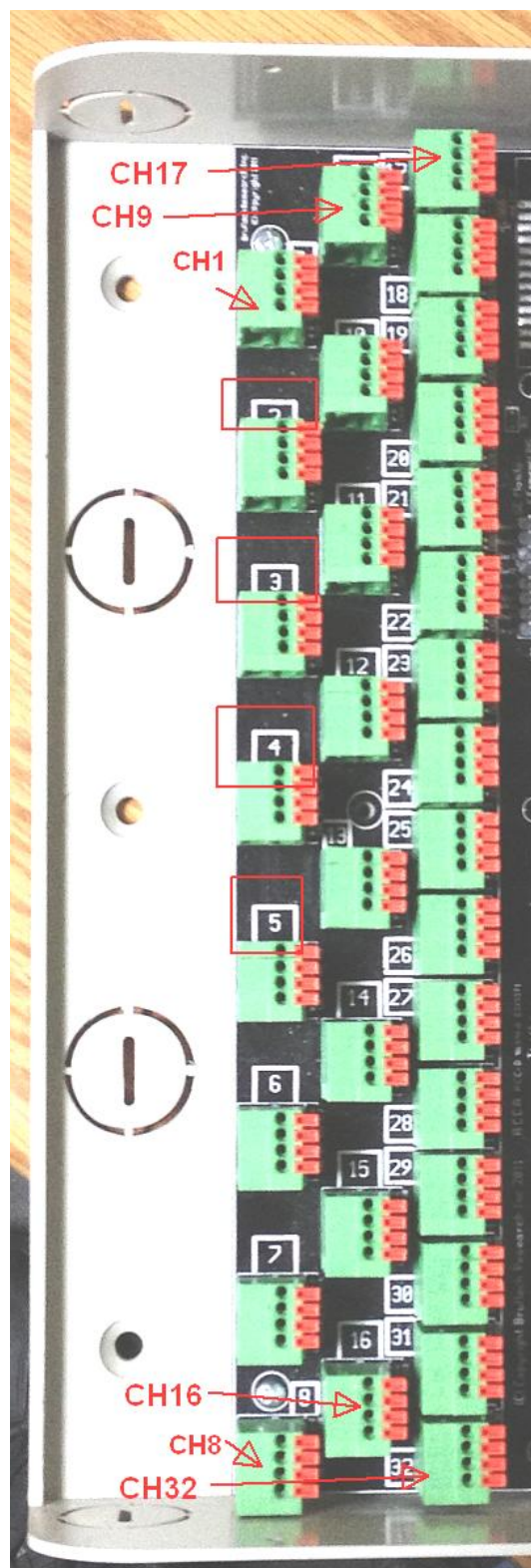
# Type A CT Connection

Again, what constitutes a "Type A" CT is the fact that the signal produced is a voltage, usually below 0.333V.

## *Single CT Connection*

**Type A** CT leads connects to terminals 1 and 2. This applies for any single "Type A" CT. When a single CT is connected to a channel, the lead polarity (lead color code) does not matter.
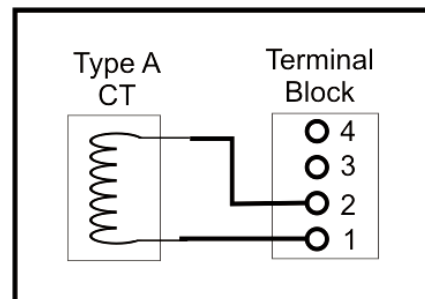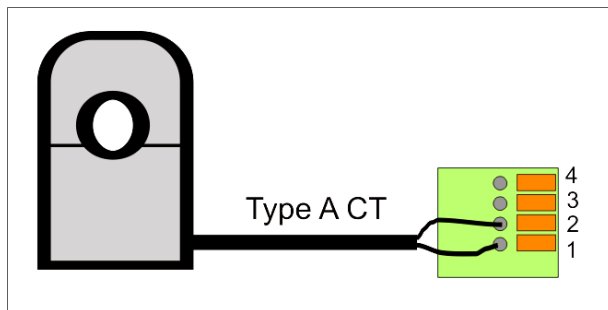


## *Dual Type A CT Connections*
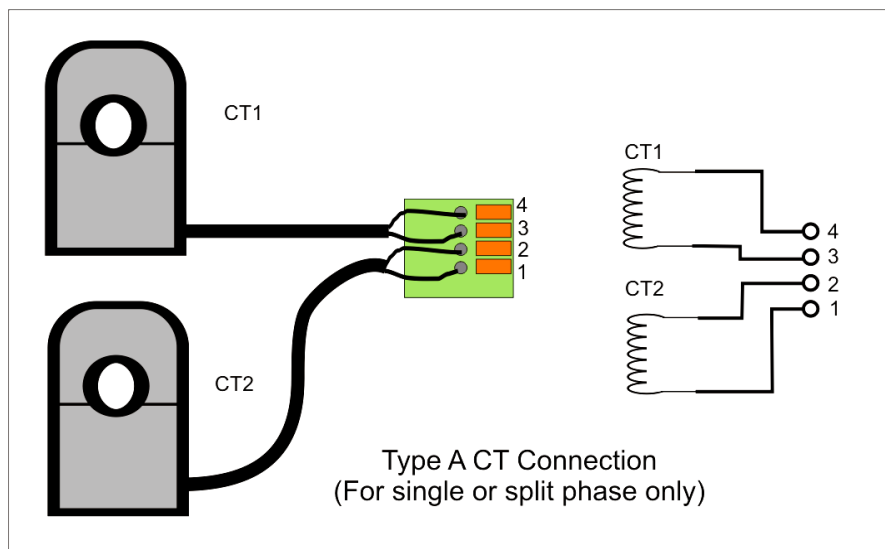


This technique for coupling two CTs on a single channel **only applies to single or split-phase** services. This cannot be done with 3-phase systems, unless the 2$^{nd}$ CT is monitoring another load located on the same phase. See 3-phase section for more information.

Both CTs must be of the same model. For example although SPLIT-100 and SPLIT-200 CTs are both Type A CTs, they may no be combined on a single channel.

It is important to pay attention to the lead polarity when more than one CT is connected to a single channel. If a mistake is made with regards to lead polarity, there will be no harm or damage as a result. The consequence of this is that the current from one CT will be subtracted from the other. For example:

*CT1 monitors a 60W load and CT2 monitors a 100W load. Improper polarity will cause the GEM to display this as a 40W load instead of 160W which is the sum of both loads.*

It is very easy to correct such a situation. Remove the leads of **one CT only** and swap the two leads….. insert the black wire where the white wire was previously and vice versa.

Sometimes it is just as easy to take the 50/50 chance a make a quick check by simply disconnecting one of the CT leads while observing the power (watt). If the power increases when the CT lead is removed, then simply swap the polarity on one CT only. This should result in an increase in power (providing there is a load on this circuit).

## Type B CT Connection

Again, what constitutes a "Type B" CT is the fact that the signal produced is a current signal, usually in the milliamp (mA) range.

### Single CT Connection

**Type B** CT leads connect to terminals 2 and 3. When only one CT is connected to a given channel, the lead polarity does not matter.
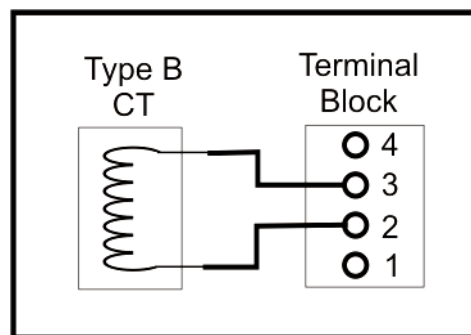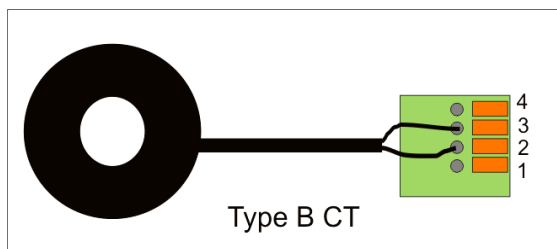


### Dual Type B CT Connections

This technique for coupling two CTs on a single channel **only applies to single or split-phase** services. This cannot be done with 3-phase systems, unless the 2nd CT is monitoring another load located on the same phase. See 3-phase section for more information.

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Both CTs must be of the same model. For example although Micro-100 and Micro-40 CTs are both Type B CTs, they may no be combined on a single channel.



Type B CT Connection
(For single or split phase only)

It is important to pay attention to the lead polarity when more than one CT is connected to a single channel. If a mistake is made with regards to lead polarity, there will be no harm or damage as a result. The consequence of this is that the current from one CT will be subtracted from the other. For example:

> CT1 monitors a 60W load and CT2 monitors a 100W load. Improper polarity will cause the GEM to display this as a 40W load instead of 160W which is the sum of both loads.

It is very easy to correct such a situation. Remove the leads of **one CT only** and swap the two leads….. insert the black wire where the white wire was previously and vice versa.
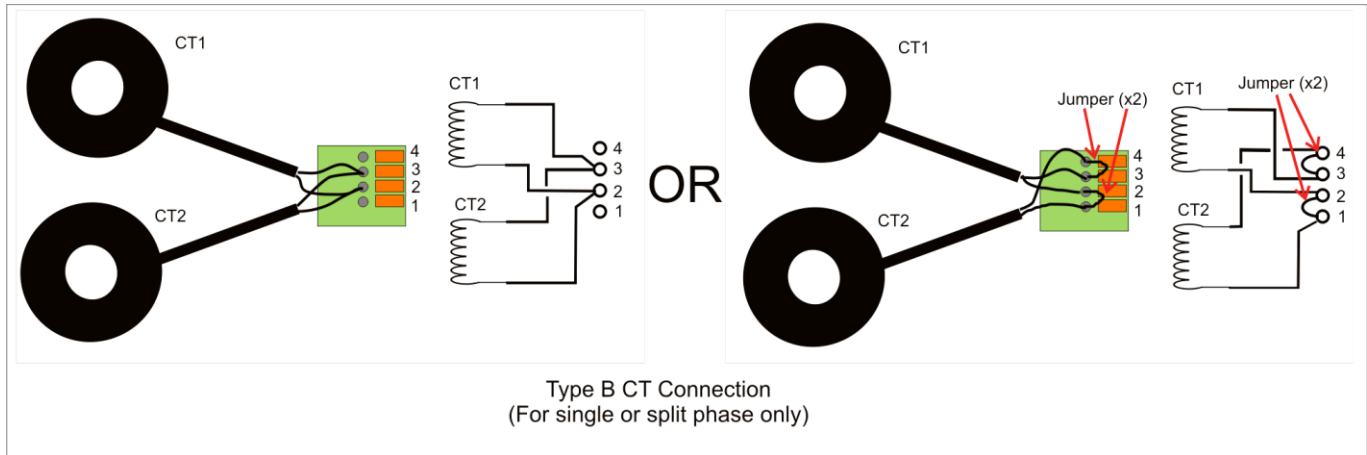
Sometimes it is just as easy to take the 50/50 chance a make a quick check by simply disconnecting one of the CT leads while observing the power (watt). If the power increases when the CT lead is removed, then simply swap the polarity on one CT only. This should result in an increase in power (providing there is a load on this circuit).

# Pulse Count Inputs

The GEM has four pulse count inputs. Pulse counter #1 and #2 are totally isolated from the GEM ground and circuit. Either of these two inputs require a DC pulse signal between 3V and 24VDC.

Pulse counters #3 and #4 are "dry" contact type counters. These inputs require switch contacts not connected to any power source, such as relay contacts or magnet switch contacts. Very low voltage from the circuit (5VDC) is used to complete the circuit.



**Pulse Counter Terminal Block**
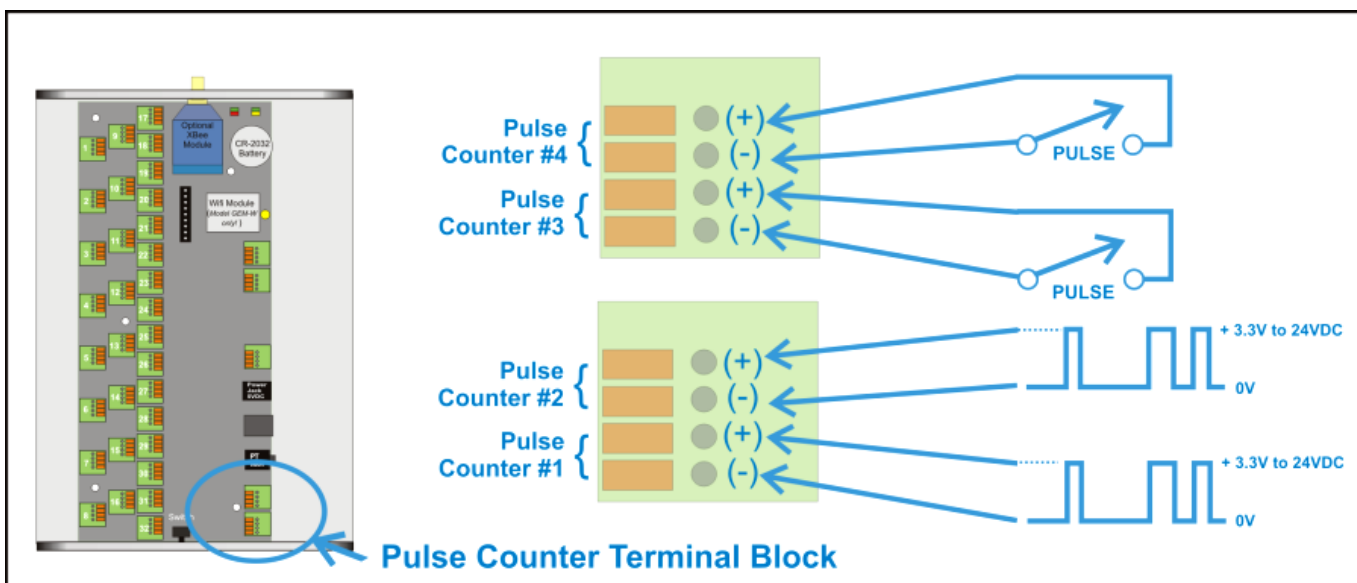
# Potential Transformer (PT) Input

The potential transformer is responsible for providing a low voltage image of the line voltage to the GEM for accurate true power calculations. This signal must be galvanic isolated to maintain safe low voltage to the GEM.

A 120VAC to 12VAC UL/CSA wall transformer (North America)  is used as a potential transformer and is included in the GEM package. Since the step down ratio is not identical for all wall transformers of the same model, the PT Type setting may altered slightly to improve voltage accuracy. This requires a true RMS DMM connected to the line voltage as a reference.

The PT Type value is increased or decreased slightly until the voltage displayed by the GEM, matches the voltage at the outlet where the PT is connected.

## CAUTION!

*Only galvanic isolated low voltage (<14VAC) PT certified by an accredited laboratory such as UL, CSA, ETL, whichever applies to your Country, may be used. NEVER connect directly to Line Voltage from the electrical panel! Failure to obey these rules can cause injury, fire or fatality!*

The GEM has two potential transformer (PT) inputs:

- A 3.5mm stereo phone jack
- A Mini USB jack

## 3.5mm Phone Jack

The 3.5mm PT input is the most commonly used. By using its "stereo" capability, this jack may accept two voltage ranges: 14VAC and 333mVAC.

Typically, the PT signal to the GEM will be from a 120V/12VAC UL/c certified wall transformer. It will connect to the GEM using a 3.5mm "mono" plug.

Potential transformers will also be available with primary (line) voltage from 120VAC to 480VAC with an output signal in the 333mV to 666mV range. These PTs are fitted with a stereo plug making connection via ring and sleeve only (tip not connected). This allows the GEM to use the lower PT range.

There is a two pin jumper located near the 3.5mm jack to change the 333mV range to 666mV. This jumper should be pre-installed based on the PT being used.
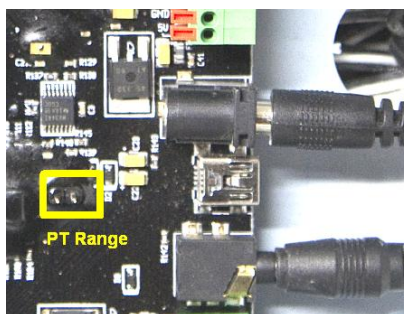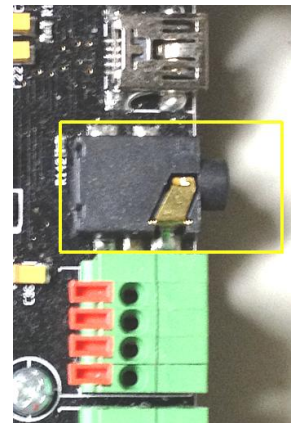
## *Mini USB Jack*

**The mini USB jack is NOT a USB communication port!**

The USB jack is for future option of a combined PT/Power Supply. The jack is configured such that the GEM may be powered using +5VDC USB power connection. The standard USB D+ and D- connections are used to supply 333mVAC potential transformer signal.
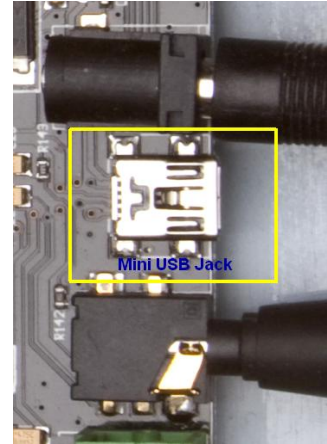


Mini USB Jack

# Power Supply Input

Power to the GEM is supplied via a 2.1mm X 5.5mm barrel plug from a +5VDC power supply (center is +). Alternately, power may be supplied by the mini USB jack instead of the barrel jack (not both at the same time). These two supplies are connected together on the PCB. It is recommended to use the supplied transformer. Id a substitute is to be used, it MUST be UL/CSA (USA/Canada) certified (or whatever certification applies to your Country).

## Power Supply Access Terminal Block

A terminal block provides access to the GEM's +5VDC and +3.3VDC power supplies. It is recommended not to use these terminals unless examples are provided in this document.

The purpose of these terminals is to provide power for future options.
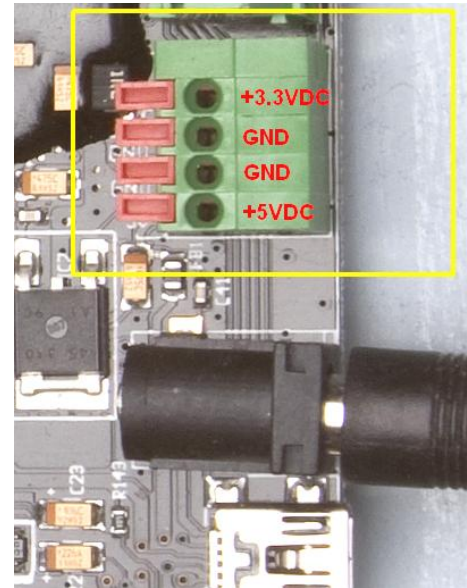
# CT Installation

All of the Brultech CTs have a marking "K ➔ L" except for the Micro CTs. This mark is used to specify the orientation of the CT when installed. "K" signifies the "source" which is where the power is coming from and "L" is the "load" which is the device receiving power.

When the CTs are installed, the arrow should point to the load. There is no harm if the CTs are installed backwards since this can be corrected by reversing the black/white leads when connecting to the GEM. Paying attention to orientation will simplify the connection process especially for 240V loads using two CTs and when connecting to 3-phase systems.



CT Orientation For
Micro-40, Micro-80 & Micro-100
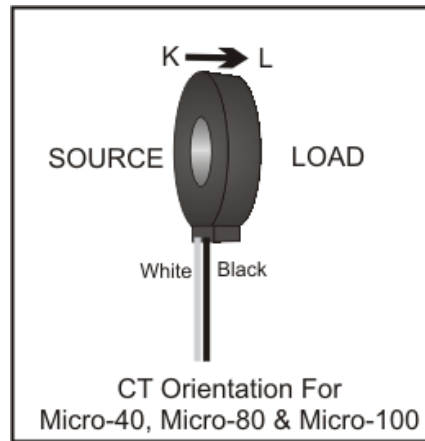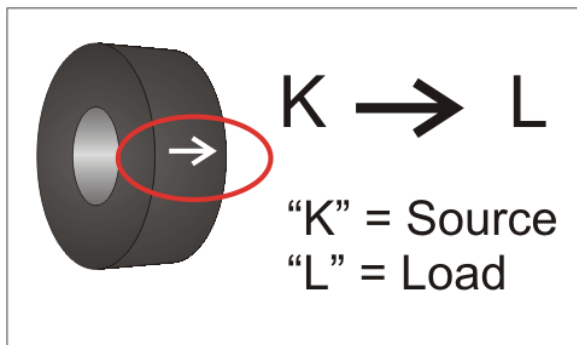
# Single/Split Phase Residential System

Almost every home in North America has its power supplied by a 120V/240V split phase service.
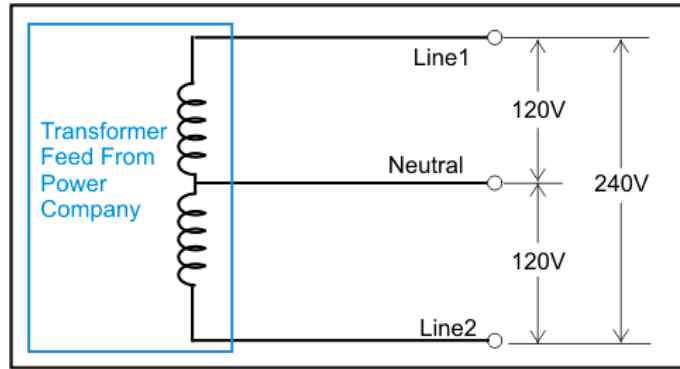


When installing CTs on a single or split phase system, it is recommended to install them such that the arrow points toward the load as illustrated in the diagram below. Following this rule will simplify the task of polarizing the CTs if more than one CT is connected to a given channel such as would be the case for 240V loads.

Some 240V loads may be monitored with a single CT as long as it does not required a neutral conductor which is common for many water heaters, baseboard heaters and some water pumps.
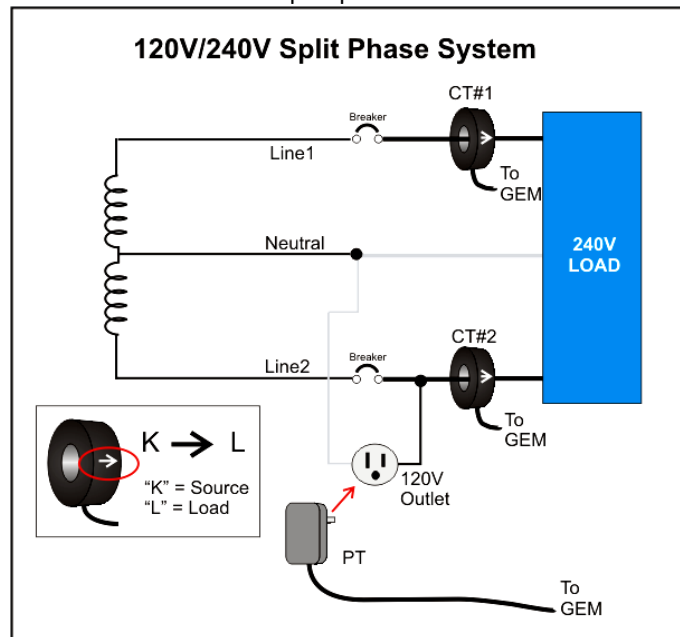
## Three Phase (Polyphase) 4-Wire Wye(Y) System

Most commercial and light industrial buildings will have three phase panels. Three phase (sometimes referred to as "polyphase") is preferred for powering large motors such as those found in rooftop AC units, refrigeration units and machinery. The most common system is the 4-wire "Y" 120V/208V feed as shown in the diagram below.
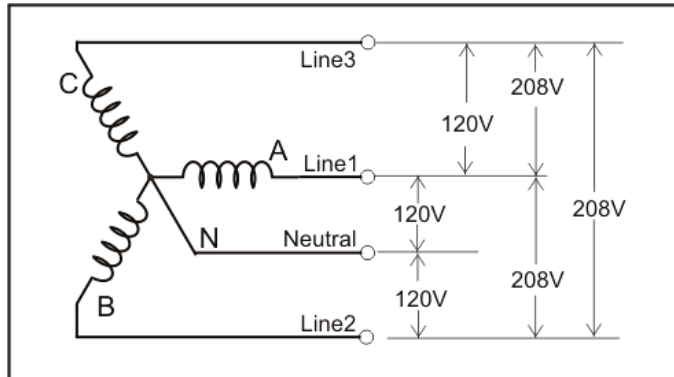


The GEM uses a unique method of monitoring the voltage of a three phase system. Typically, energy monitors require all three voltages to be monitored. The GEM simplifies matters by monitoring a single voltage phase. The diagram above shows how the simplicity of the installation since the voltage is obtained via a wall-transformer. Other PT solutions are also available that allow monitoring 3-phase systems up to 480V.

When setting up the GEM's input channels, one of the parameters required for 3-phase systems is the phase for a given channel: A, B or C. The following paragraph describes how to determine the proper setting.
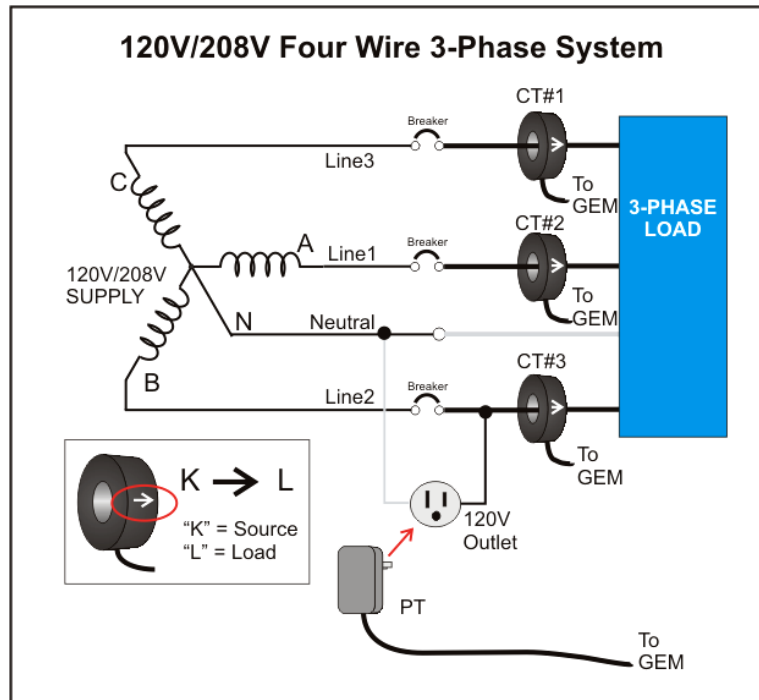


In the diagram above, CT#3 will be configured for Phase A because the PT is connected between Neutral and Line2.

**The important step is to note which phase (or Line) connects to the outlet which powers the "PT".** This is the reference and will always be considered "Phase A" when configuring the GEM. For example in the diagram above, the "120V Outlet" is connected to "Line2", therefore the circuit that "CT#3" (which is connected to the Line2 load) is sensing will be configured for "Phase A. In this example, since Line2 = Phase A then:

> Line3 = Phase B
> Line1 = Phase C
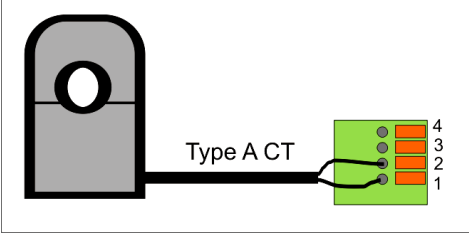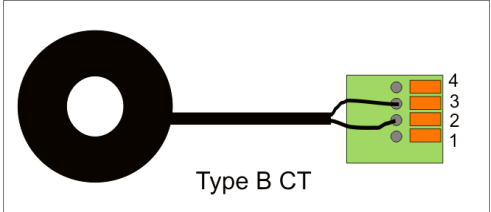
Based on this example, the channel that CT#1 is connected to will be configured for "Phase B" and CT#2 channel will be configured for "Phase C".

To summarize, here are the possible combinations:

| 120V Outlet (for PT) connected to Line1 | 120V Outlet (for PT) connected to Line2 | 120V Outlet (for PT) connected to Line3 |
|---|---|---|
| *Line1 CT = Phase A* | *Line1 CT = Phase C* | *Line1 CT = Phase B* |
| *Line2 CT = Phase B* | *Line2 CT = Phase A* | *Line2 CT = Phase C* |
| *Line3 CT = Phase C* | *Line3 CT = Phase B* | *Line3 CT = Phase A* |

## *CT Connection (Four-Wire WYE System)*

Depending on the CT type used, the color code for the connecting leads should be as indicated in the table below. When setting up to monitor a three phase WYE system or load, only one CT is allowed per channel. The technique used to couple two CTs on a single channel only applies for single/split phase systems and NOT for three phase systems.

| Type A CT | Type B CT |
|---|---|
|  |  |
| **Terminal 1:** White Lead (Or black with white stripe)<br>**Terminal 2:** Black Lead | **Terminal 2:** White Lead (Or black with white stripe)<br>**Terminal 3:** Black Lead |

## *Displayed Polarity*

Once the CTs have been connected and it is time to setup the connected channels, the "Phase A" channel should be setup first. This is the CT channel which connects to the same phase as that which the PT is connected to.

Connect to the GreenEye Monitor using the setup program and make sure you have a connection established. (See "Setup Software" manual for more information).

Select "System" from the setup program and make sure the "Polyphase" option is enabled. Click "Save Settings".

Select "Channels" from the setup program, then refresh the values by clicking the "Update Summary" button. All CT settings and corresponding phase settings will be displayed. Set the CT values (type and range) then set the phase values as determined by the table (above).

Let's first concentrate on the "Phase A" channel. Select the "Real-Time Data" tab of the setup program. Make sure that the load is consuming power and that a wattage value is displayed for phase A. If the displayed watt value for phase A is a negative value, then you can easily rectify this by unplugging the PT, giving it half a turn and re-plugging it such that the two prongs are reversed. This will cause the negative value to because positive.

Verify that phase B and C channels have positive values such as phase A now does. If this is not the case, try changing the phase B channel configuration to C and likewise phase C to B. This should provide positive values for all three phases.

Given a three phase load, the total power for that load will be the sum of all three channels used to monitor it.

In some cases, you may encounter a load such as a water heater using only two of the three phases. The procedure is the same. Remember that there is a possibility that the heater uses only phases B and C. Again the same principle applies, simply disregard the unused phase and the total power is the sum of the two phases used.

## Three Phase (Polyphase) 3-Wire Delta (∆) System

# Communication Link

The GEM provides a multitude of hardware communication options such as RS-232 which is standard on all GEM models. Optionally, WiFi, Zigbee® (XBee® module), Ethernet or other options are available. The "other" options is based on a header provided with "UART" access for those requiring a custom solution such as RS-485, Z-Wave® or other such solution.

Along with all of the hardware options, the GEM offers various packet formats and APIs for communicating with data hosts.

## COM Ports

The GEM uses two communication ports: COM1 and COM2. In general, data from both ports are identical.



Each COM port is accessible via one of two RS-232 ports: RS-232(1) and RS-232(2). Any of the optional communication options described previously will share a com ports with its corresponding RS-232 port. For example, the RS-232(1) connection will receive the same data as that being sent to the WiFi module. This means that when the GEM sends a data packet or response to a command, the data will be transmitted via WiFi and RS-232(1) serial port. See diagram below.
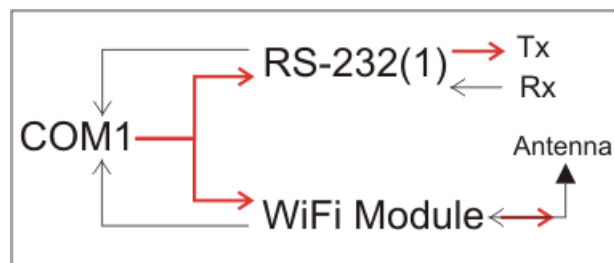


Figure x

If command data is sent to the GEM via the RS-232(1) serial port, the WiFi module will not "hear" this command. The same applies if data is sent to the GEM via WiFi. See diagrams below.
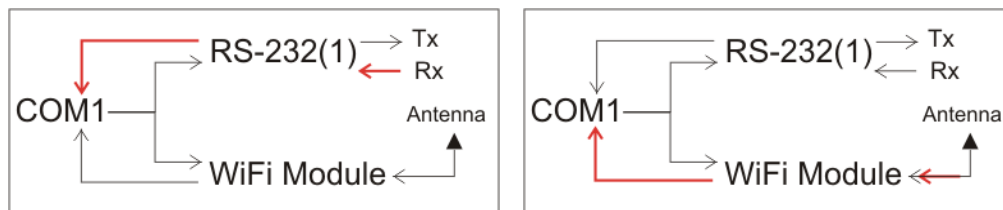
Figure x

The same concept applies to other shared COM ports.

Here is a summary of how the COM ports may be shared:

**COM1** is connected to **RS-232(1)** and may be shared with __only one__ of the following optional devices:

- WiFi Module
- Ethernet Module
- Combination WiFi/Ethernet Module
- Custom PCB connected to the 1 X 10 pin header (3.3V TTL level signal). **\*NOTE:** Improper connection to the header may damage the GEM and void warrantee. Consult Brultech before experimenting with this port.
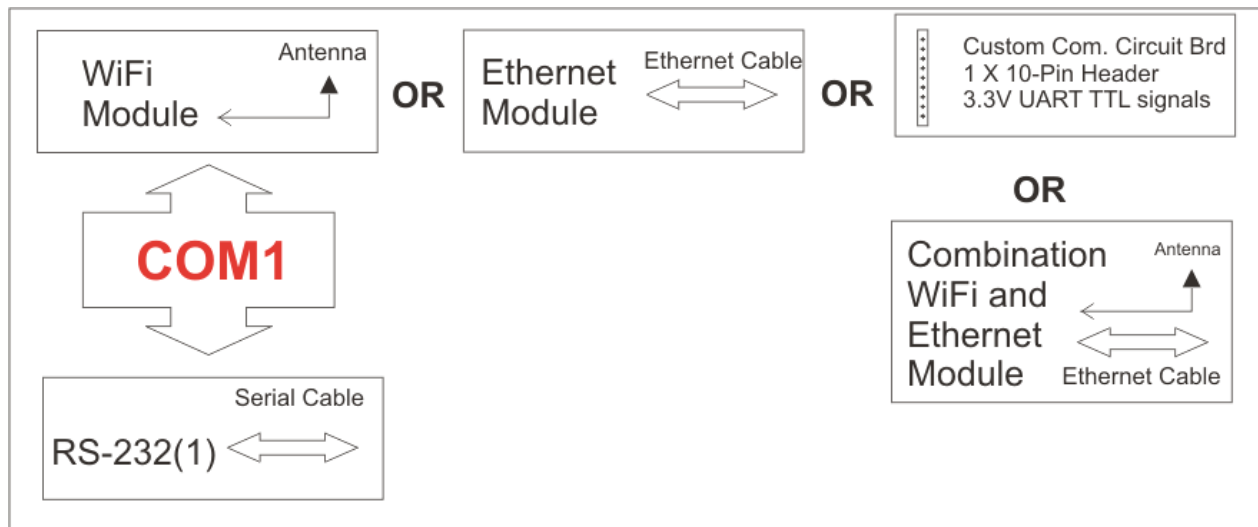
**COM2** is connected to RS-232(2) and may be shared with __only one__ of the following optional devices:

- XBee® Module
- Device compatible with the XBee® module footprint and pin-out
- Custom PCB connected to the 1 X 10 pin header (3.3V TTL level signal).* Improper use may damage the GEM and void warrantee. Consult Brultech before experimenting with this port.
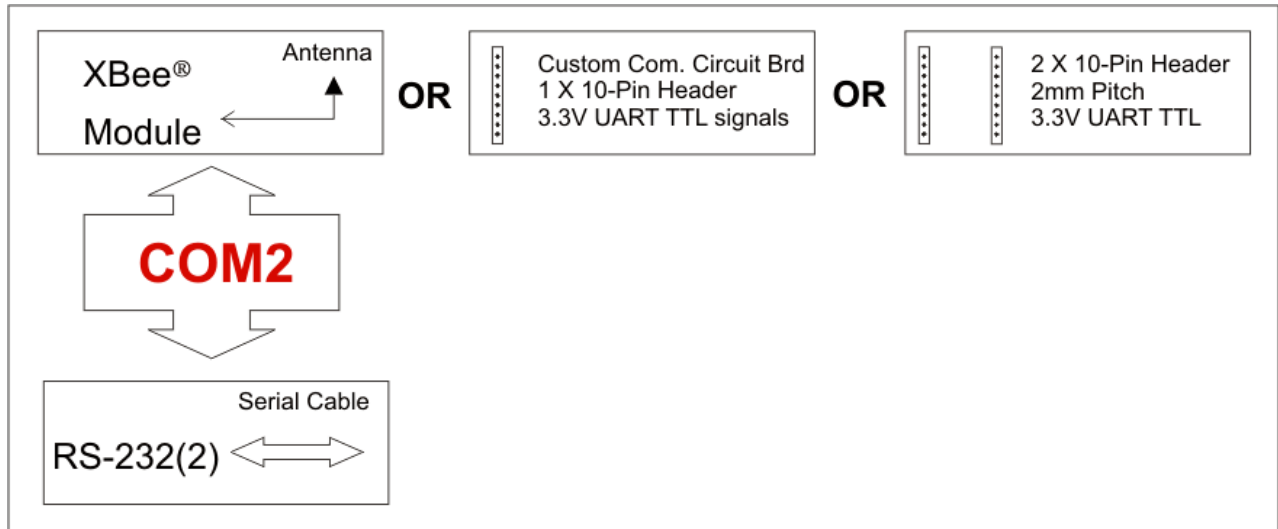


## COM Port Bridge Mode

For setup purposes, there is a method whereby a serial port or communication device can talk directly to one another as long as each is on a different COM port. This is done using "Bridge Mode". This mode creates a virtual connection between a COM1 and COM2 device.
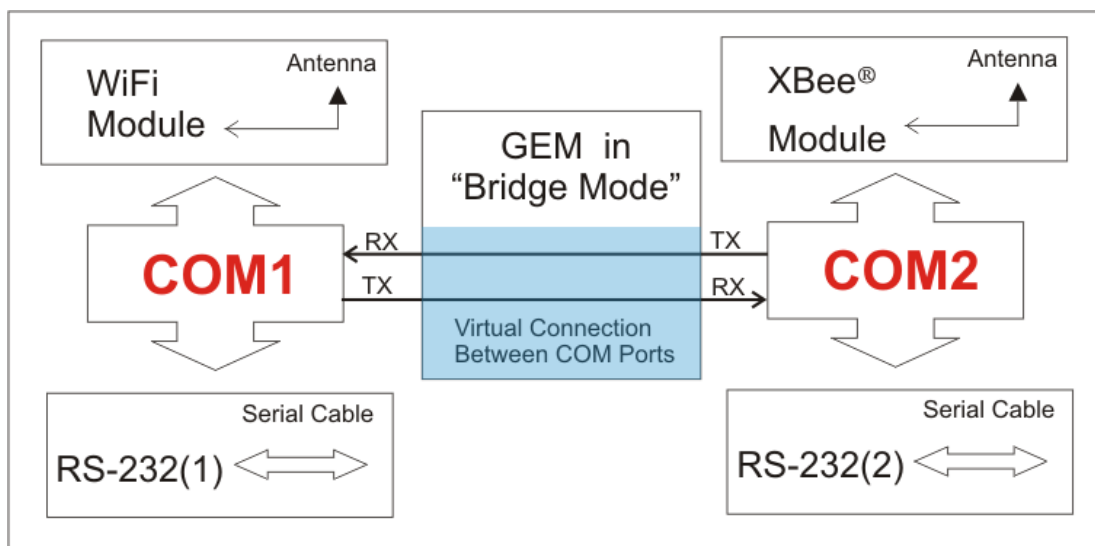


The purpose for this is to enable setup or firmware upgrades for specific communication devices. For instance, an XBee® module's firmware may be upgraded by connecting to RS-232(1) and bridged to communicate directly with the XBee®

module. Another common use would be to connect to the RS-232(2) port and setup parameters for the WiFi module (if present).

Bridge mode is baud independent which means that the virtual wire section will work at any common baud rate without any required configuration. The baud rate setting for each device must however be the same. For example, if you are bridging an XBee® module to setup the WiFi module, both devices must be set to the same baud rate. Bridge mode does not support hardware flow control.

When the GEM is in bridge mode, it no ceases all operations and only operates as a bridge. Bridge mode is exited by a special timed command sequence or simply by momentarily pressing the GEM's push button switch (14).
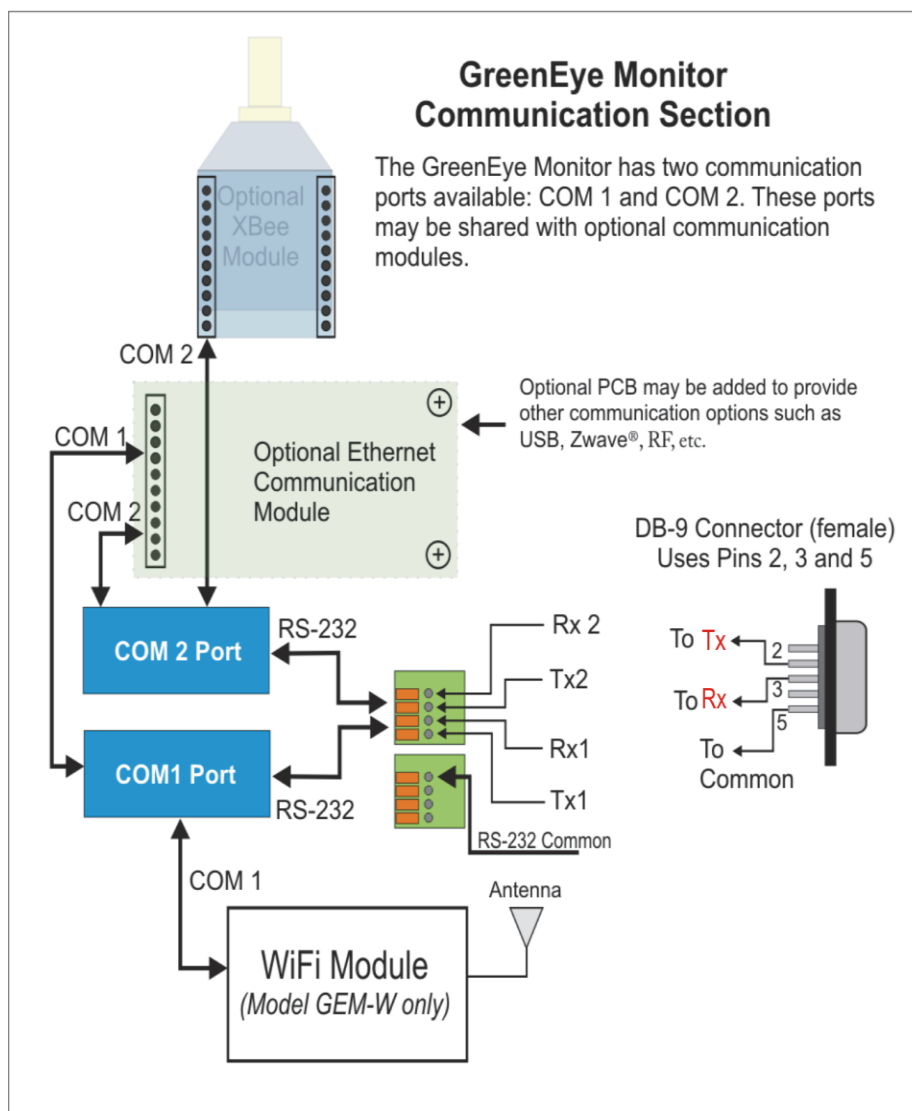
## RS-232 Port

Every GEM device comes with two RS-232 ports. The RS-232 port may be used to connect directly to an automation system, a "Serial to Ethernet" device such as "EtherPort" or to a serial to USB adaptor. Either of these ports may be used at the main communication gateway or simply to configure the GEM, the GEM's (optional) WiFi module or the GEM's (optional) XBee® module.

The GEM is capable of being put in "Bridge Mode" which causes Com1 and Com2 to be linked together so that the RS-232 port can talk directly to a module on the opposite port.

Connection to the RS-232 port is accomplished via terminal blocks #8 in the "layout" section.

Typically only one RS-232 port would be used therefore there is only one common (GND) connection available.
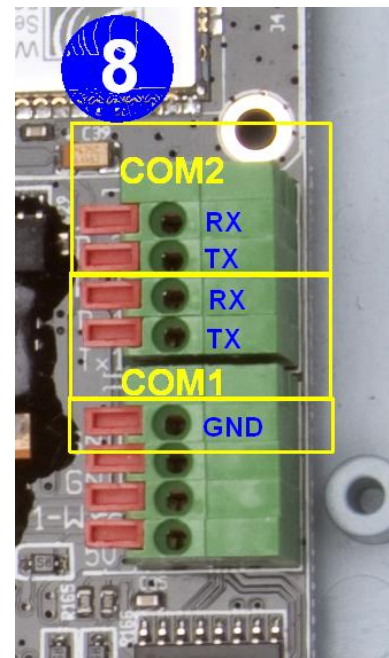
## WiFi Communication Option

**NOTE:** *This option will soon be discontinued due to erratic performance of Roving Networks' RN-171 WiFly Module*

The model GEM-W is equipped with a WiFi module. The module is initially configured so that a PC with WiFi can connect to it in ADHOC mode for the purpose of setting it up to access a local wireless router. Once this setup is completed, the GEM then connects to the WiFi router as a client.

Before the WiFi module is configured, you must determine the destination for the GEM data. This destination is where the data will be hosted such as:

- A energy monitoring hosting site (check-it.ca, smartenergygroups.com, etc)
- Brultech local web-server/dashboard
- Your own personal website
- A local computer

The WiFi module communicates via COM1 port, therefore if RS-232 communication is required, COM2 RS-232 should be used.

## Ethernet Module Option

The Ethernet module provides a robust connection to a network or PC. It is typically setup as a client although it may be configured as a server. The mode selected mostly depends on the data hosting method selected. Currently our options consist only of client mode applications although some customers have created custom software requiring the GEM to be setup as a server.
The Ethernet module may be configured using the EtherX Configuration software available on our website.

## Combination WiFi and Ethernet Communication Option

This preferred option provides a robust WiFi and Ethernet connection. Configuration is done via web browser connected to the internal website. Both options may be used simultaneously. Both options use COM1 leaving COM2 open for RS-232 or XBee® module.

## XBee® Module Option

The XBee® module provides a wireless link using ZigBee® communication via "mesh" network. The GEM incorporates a module socket for easy installation of the two most popular module types: whip antenna or RPSMA antenna connector.

The baud rate must be changed from XBee's default 9600 baud to 19,200 baud.

Since the ZigBee protocol has a limited data throughput and the GEM packets are fairly large, the GEM may be configured to send ZigBee data in specified chunk sizes along with a specified time between chunks.

Hardware flow control may also be enabled to further protect the module from buffer overrun.

## Custom Com PCB Header

There is a footprint on the GEM to accept a custom designed communication circuit board. This is available only if the GEM does not have a WiFi or Ethernet module installed.

The purpose for this footprint is to allow the development of a custom communication circuit board which would allow an alternate communication method such as RS-485, RS-422, Z-Wave, etc. Additionally, the PCB developer may wish to include a processor on board to incorporate proprietary API, functions, security, etc. The header consists of a 10-pin female socket with a 2mm pitch.

1. Ground/Common
2. Vcc +3.3V
3. COM1 Reset (output) Low Active
4. COM1 CTS Flow Control (input)
5. COM1 Tx (output)
6. COM1 Rx (input)
7. COM2 Tx (output)
8. Green LED (hi active)
9. Yellow LED (hi active)
10. COM2 Rx (input)

**NOTE**: Please contact us for more information before using this header. Improper use may damage the GEM.

# Firmware Upgrades

It is very important establish a robust communication link with the GEM before performing firmware upgrades.
The GEM has two processors, "COM" and ENG". Each processor has its own specific firmware with "GEM_C" or "GEM_E" as part of the filename followed by the version number. Example:

- COM firmware file: **"GEM_C Firmware 1.59.fmw"**
- ENG firmware file: **"GEM_E Firmware 1.36.fmw"**

It is not always required to upgrade both processors. Typically the COM processor may require upgrades as more features are made available. The ENG firmware may not need to be upgraded.

Firmware upgrade is accomplished using a PC in conjunction with the GEM Setup Application. This program is a Java ".jar" application which runs on Windows®, Linux® or Apple®.

The PC connects to the GEM using any of the available communication links:
- Ethernet
- WiFi
- XBee®
- RS-232
- USB , via serial to USB cable

If a USB or Serial connection is used instead of a TCP/IP connection, a bridge application will need to be used to bridge the Serial connection to a TCP/IP connection compatible with the GEM setup program.

As mentioned earlier it is important to have a good wireless connection when upgrading the firmware. If the wireless signal is week or intermittent then it is recommended to move the wireless devices in closer proximity.

## COM Processor Firmware Upgrade

The COM processor is the GEM's main processor. It is also responsible for coordinating data flow when upgrading the ENG processor. There could be a situation whereby the COM processor's firmware becomes corrupt during an upgrade due to interruption in communication. If this occurs, the GEM will no longer be functional. Fortunately there is a procedure to recover from this situation as explained later in this chapter.

The most recent firmware file may be downloaded from our website. Notes indicating issues resolved or features added for each firmware version are also available and should be viewed before upgrading. This will discourage needless upgrades if the changes do not affect your application.

A communication connection between the GEM and a PC running the "GreenEye Monitor Setup" program will have to be established. If the GEM is configured to send data to an online hosting site the communication module may need to be re-directed to the PC unless a secondary communication method is available. For example, if data is forwarded to an online host via WiFi or Ethernet connection (GEM COM1), firmware upgrade may be performed using any of the COM2 options such as RS-232 or XBee® module. If no other COM2 option is readily available, the TCP/IP connection will need to be redirected from the online data host's IP address to that of the PC. The procedure for doing this will depend on the type of communication module used.

Once a communication link is established between the GEM and the PC running the GEM setup program, the procedure for upgrading the firmware is:

1. Verify that the communication link is established by verifying that the GEM setup program's "Connection Status" indicates "Connected" inside the green box on the top left window of the program.
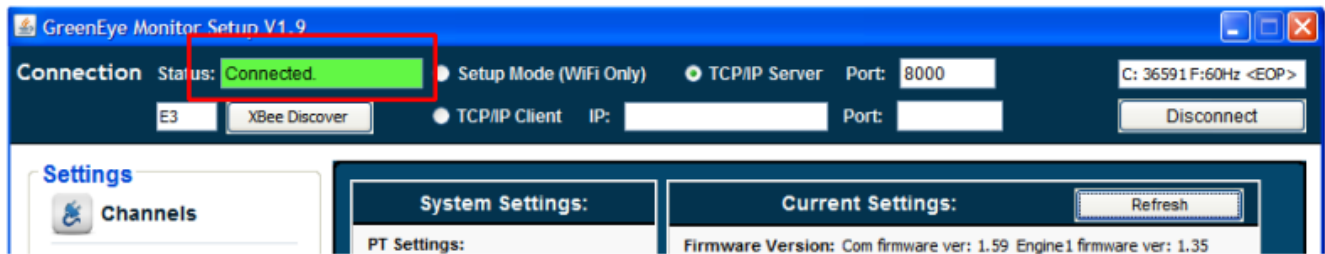


2. Click "System" from the left menu.
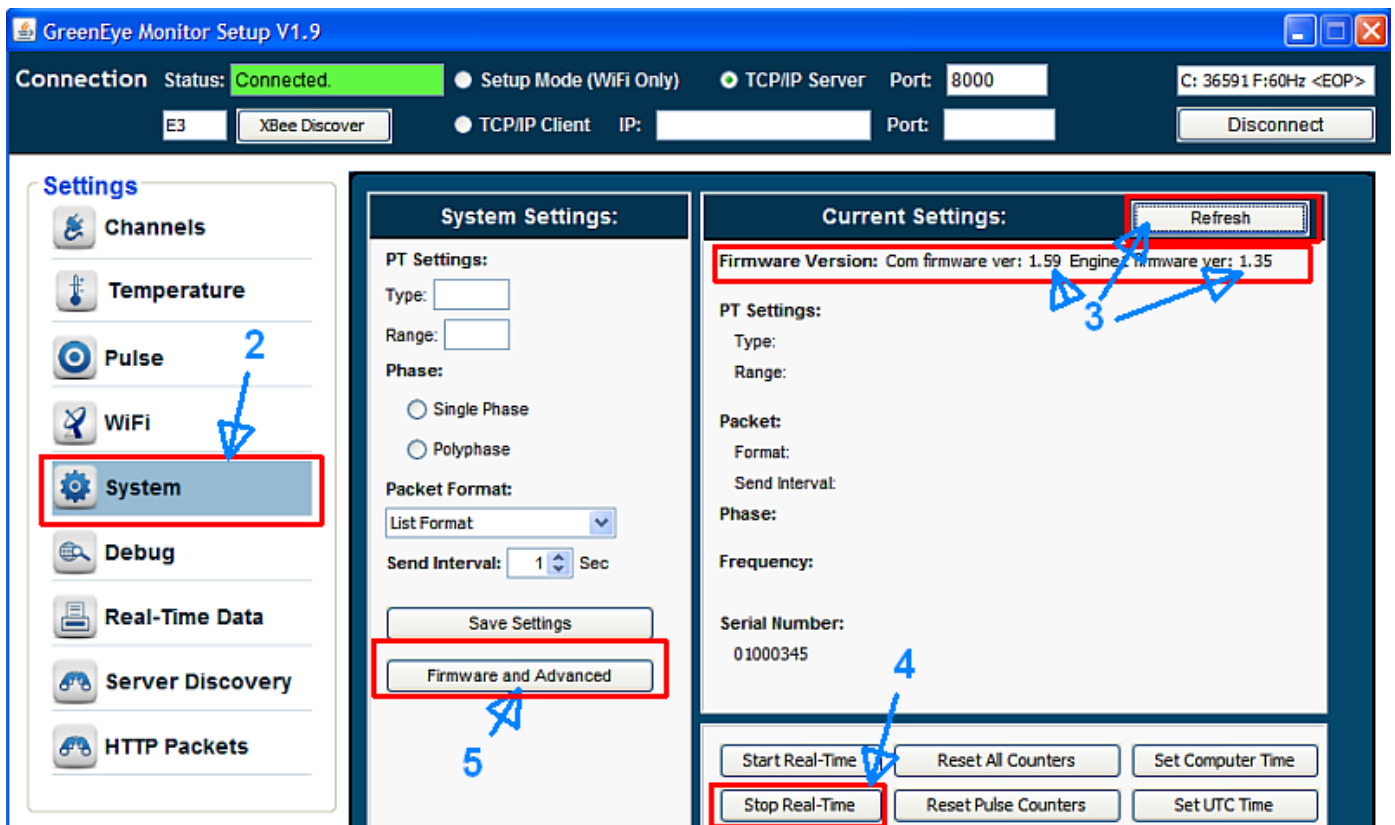


3. Click "Refresh" and take note of the current firmware version
4. Click "Stop Real-Time".
5. Click "Firmware and Advanced". This will open a new window.

6. Click "COM Firmware". A window will open
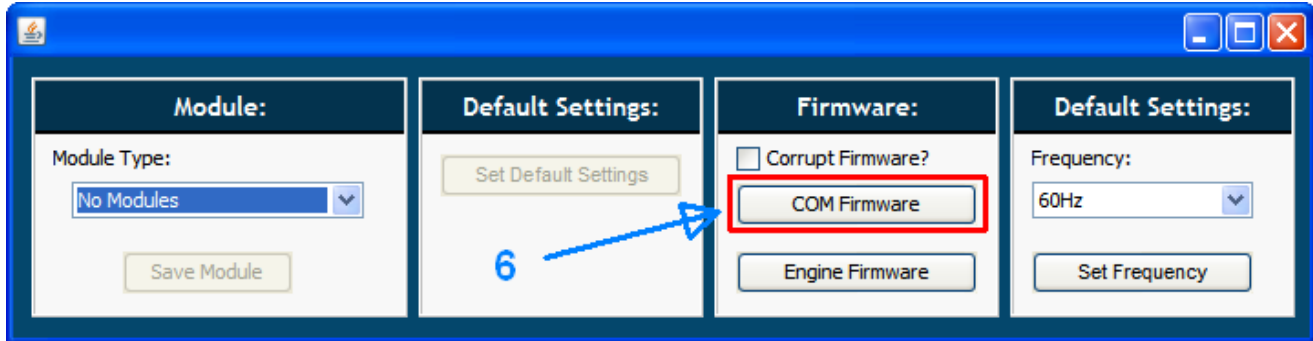


7. Click "Select Firmware". Select the firmware file.
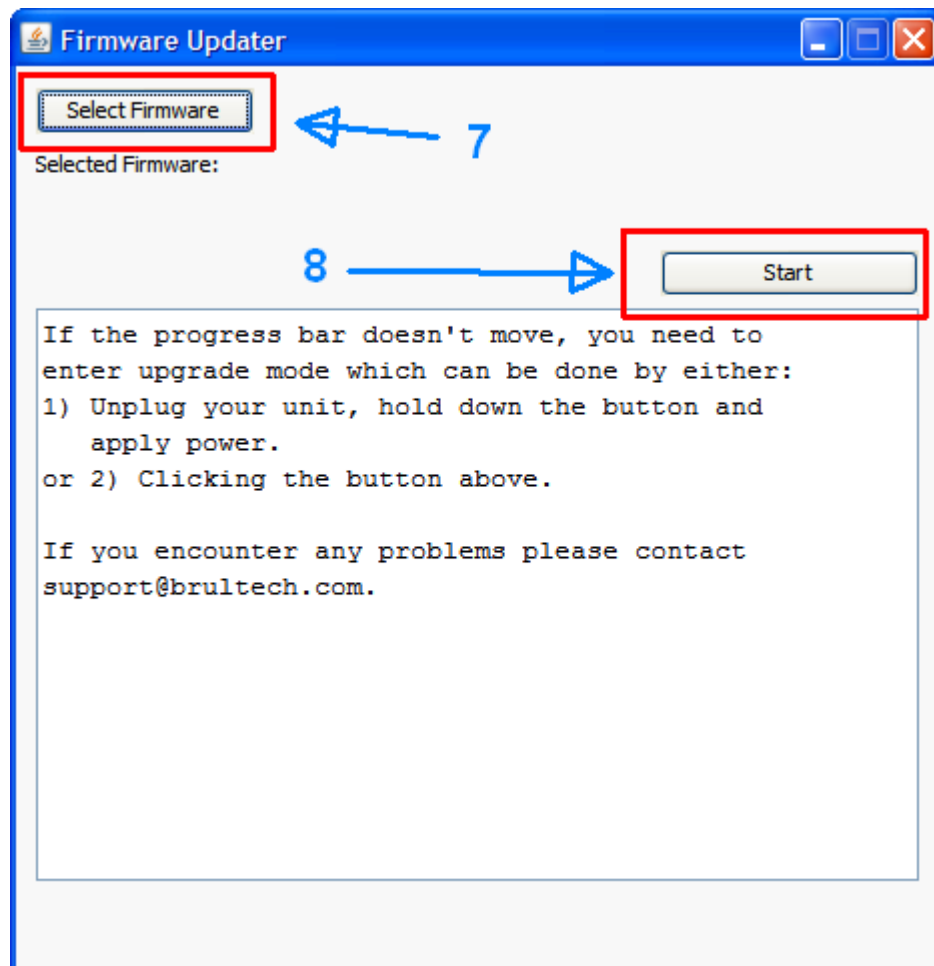


8. Click "Start"

Depending on the communication link, it may take a couple of minutes for the upgrade to complete. Pay attention to the trail of dots generated as data is transferred.

If for any reason the GEM stops responding midway through the upgrade wait several seconds since there may be a pause in data transfer when using WiFi or XBee®. If there is no response for 1 minute or so and the upgrade has not completed. Something may have occurred to corrupt the firmware. If so, follow the procedure in "Recovering from corrupt COM firmware" section below.

## Recovering From Corrupt COM Firmware

Firmware may become corrupt if data communication is interrupted while upgrading firmware. In the event that this happens, the GEM will not function properly if at all. There is a special procedure used to recover from such scenario:
1. Remove power (5VDC) from the GEM.
2. Remove the CR-2032 battery
3. While holding down the PB switch, power up the GEM
4. Once the GEM is powered, release thee PB switch. The system LED (left) will glow a solid red
5. Establish a robust communication link between the PC and the GEM
6. Make sure the "Corrupt Firmware" checkbox of the GEM setup program is checked

## ENG Processor Firmware Upgrade

The procedure for upgrading the ENG firmware is the same as that for the COM firmare (described above) with the following differences:
1. Once a communication link is established, send a "Reboot COM" command. This is done by clicking the "Debug" menu and clicking "Reboot COM" command.
2. In step 6, click "Engine Firmware" button instead of the "COM Firmware" button.

If the ENG firmware upgrade fails for any reason and the ENG firmware becomes corrupt, the method for recovery is different than that of the COM firmware.

## Recovering From Corrupt ENG Firmware

Recovery from a failed ENG firmware upgrade is different and simpler than that for the COM corrupt firmware. Simply press the PB momentarily so that the SYS LED returns to green then repeat the procedure.

DO NOT CHECK THE "Corrupt Firmware" OPTION IN THE SETUP PROGRAM! This option only applies to the COM firmware.

If the GEM is at a remote location and the PB cannot be pressed, simply wait for 80 seconds as the GEM will automatically exit the ENG firmware upgrade function. Again, the ENG firmware upgrade can be attempted again.

# Technical Specification

## Power Metering

| | |
|---|---|
| **Number of Channels** | 32 (expansion available in the future) |
| **Measurement** | POWER:<br>• True (or Real) Power using high speed volt and current sampling<br>VOLTAGE:<br>• True RMS |
| **Accuracy** | Power/Energy Measurements:<br>• Typically +/- 1% plus CT accuracy<br>Voltage Measurement:<br>• Better than 1% with PT-Type value trimmed to a reference. |
| **Sampling Frequency** | Voltage sampled @ 20.8 kHz<br>Current sampled @ 10.4 kHz |
| **Maximum Input Current** | Dependent on current transformer. Currents greater than 1,000A may be monitored. |
| **Current Transformer Input** | Type A CT with AC mV output:<br>• 700 mV max for single CT<br>• 350 mV max for each of two connected CT on a given channel<br><br>Type B CT with AC mA output:<br>• 103 mA max for single CT<br>• 51.5 mA max for each of two connected CT on a given channel<br><br>**NOTE:**<br>• Exceeding the specified input values will affect channel accuracy.<br>• Connecting a Type B CT to terminals designated for TYPE A CTs may cause a channel overload to the point that all channels display unpredictable power values |
| **Input Impedance:** | • 1,000 ohms for Type A CT connection. Terminals 1&2 and 3&4<br>• 6.8 ohm (burden resistor) for Type B CT connection. Terminals 2&3 |
| **Potential Transformer Input** | 3.5mm Jack PT Input:<br><br>• Mono plug PT signal 8VAC to 18VAC. Voltages greater than 14VAC require a PT shorting jumper to attenuate PT signal.<br>• Stereo plug: "sleeve" and "ring" connection, "tip" not connected. 333 mVAC without PT shorting jumper or 666mVAC with shorting jumper.<br><br>Mini USB Jack Input:<br><br>• PT signal to pins 3 and 4 of mini USB<br>• 333 mVAC without PT shorting jumper or 666mVAC with shorting jumper |

| | |
|---|---|
| **Potential Transformer (PT)** | GEM supplied with UL/c wall transformer with < 2 degree phase error.<br><br>Optional PT (part number PT01) may be ordered:<br>• 1% accuracy<br>• Input voltages between 120V to 480V.<br>• 600V rated leads |
| **Load/System Types** | Single and Polyphase systems. |
| **System Frequency** | 50Hz or 60Hz. Default is 60Hz. May be configured for 50Hz via setup software. |
| **Resolution** | Power: 1 Watt<br>Energy: 1 Watt-Second (.000000277 kilowatt-hour)<br>Voltage: 0.1 Volt |
| **NET Metering** | All channels are capable of NET metering. Two sets of watt-second counters are used for energy flow direction. |
| **Watt-Second Counters** | Each channel has two 5-byte incrementing watt-second counters, one absolute and one polarized.<br>Counter "wrap around" occurs after $2^{40}$ watt-seconds or 305,419 kilowatt-hours. |

## Pulse Counting

| | |
|---|---|
| **Pulse Counting Channels** | Four Individual pulse counters<br>• Two dry contact inputs<br>• Two DC pulse inputs |
| **Counter Input** | Counter #1 and #2:<br>• Requires DC pulses<br>• Galvanic isolated from GEM system via opto-isolator<br>• Requires DC pulses between 3.5 and 24VDC. (5VDC ideal)<br>Counter #3 and #4:<br>• Requires "dry" contact closure from reed switch, relay, etc.<br>• Input is not isolated from the GEM power supply therefore connection to this input must be isolated from the pulse source's power supply. This is typical when using reed switches. |
| **Pulse Frequency** | Less than 1pps (pulse/second)<br>*Subject to change |
| **Pulse Width (Duration)** | Minimum pulse duration 550ms.<br>*Subject to change |
| **Counter Registers** | Each counter has a 3-byte up-counter<br>Counter wraps around when full $2^{24}$ pulses. |
| **Counter Volatility** | Counter values are stored in RAM and preserved by battery power when a power interruption occurs. |

## Temperature Sensing

| | |
|---|---|
| **Temperature Sensor Channels** | 8 Channels |
| **Sensor Type** | Uses 1-Wire Bus system<br><br>Compatible with the following 1-Wire sensor types:<br>• DS18B80<br>• DS18S80 |
| **1-Wire Bus** | Uses three push terminals:<br>• GND<br>• DATA<br>• +5 VDC<br>"1-Wire" devices are connected in parallel<br>For more info visit: http://www.1wire.org/ |
| **Conversion Interval** | All temperature sensors perform a temperature conversion every 16 seconds |
| **Sensor Read Interval** | Each enabled temperature sensor is read once every 64 seconds<br>One of eight temperature sensors is read every 8 seconds, hence 8 X 8 = 64 sec |
| **Temperature Units** | The GEM may be configured for Celsius or Fahrenheit degrees |
| **Temperature Resolution** | $0.5^o$ C resolution. Fahrenheit degree values are derived from the C value and converted to 1 decimal point accuracy. |

## Communication

| | |
|---|---|
| **Standard Communication Ports** | • RS-232 via COM1 and RS-232 via COM2<br>• 19,200 baud 8-bits, no parity, one stop bit (8N1)<br>• GND, TX, RX no hardware flow control<br>• Connection via "push terminals" |
| **Optional Board SMT Soldered WiFi Module** | Uses Roving Networks RN-171 WiFly Module<br>• Receive Sensitivity: -83dB typical<br>• Output Power: 12 dBm<br>• Serial Communication 19,200 baud<br>• On board wire whip antenna |
| **Ethernet Module** | Uses third party Ethernet Module<br>• Supports: TCP, UDP, ICMP, IPv4 ARP, IGMP, PPPoE, Ethernet<br>• Client, Server and Mixed modes. Default is "Client" mode<br>• 10BaseT/100BaseTX Ethernet PHY<br>• Configured via UDP using simple setup application |

| | |
|---|---|
| **WiFi+Ethernet Module** | Provides Both Wifi and Ethernet Options simultaneously |

**WiFi+Ethernet Module** — Provides Both Wifi and Ethernet Options simultaneously
- Support 802.11b/g/n wireless standards
- Output Power:
  - 802.11b: +20dBm
  - 802.11b: +18dBm
  - 802.11b: +15dBm
- Web Configuration Page
- Supports WEP/WPA-PSK/WPA2-PSK/WAPI
- Encryption: WEP64/WEP128/TKIP/AES
- RP-SMA 2dBi external antenna

**XBee® (ZigBee®) Module**
- Socketed for Digi International XBee® ZB modules
- Accepts any of the three ZB-24 module antenna options
- Communicates at 19,200 baud
- Hardware flow control may be enabled
- GEM setup option provides the option of chunking data to XBee® modules in order to limit data flow restrictions inherent with ZigBee® protocol

**Data Communication:** Real-Time Data:
- May be configured to "push" energy usage data at a user defined interval or "pull" data via API
- Various data packet formats available
- May be configured to post data using "POST" or "GET" methods
- Efficient binary packet options available
- Packet formats available for custom software development
- Custom packet formats may be available based on the project size

Setup and Setting Commands
- Documentation available listing the commands used to read or write GEM setup parameters

**GEM Firmware Upgrades** Firmware upgrades may be accomplished using any of the communication options above including USB if a "serial to USB" adaptor is available.

**Alternate Communication Options** Custom communication solutions are available via a 10-pin header or XBee® socket header providing access to UART TTL COM1 or COM2 ports.

**NOTE:** Contact Brultech support before attempting to use these headers! Improper use may damage the GEM and void warranty

## GEM System

**Power Supply** Volt and Current:
- 5VDC +/- 5% UL/CSA approved
- 1.5A AC Adaptor (typically uses less than 200mA depending on communication module used)

Consumption:
- Typically less than 1 watt

Power Connection:
- 2.1mm X 5.5mm barrel jack, center positive (standard)

- Optional power connection via mini USB jack instead of barrel jack

**Isolation**
- The GEM must not be installed in the electrical breaker panel!
- All connection to the GEM must have galvanic isolation to the power-line
- Signals to the GEM must be Class2 low voltage
- Current transformers (CT) and the Potential Transformer (PT) connected to the monitored electrical panel must be UL/c listed and suitably rated above the maximum voltage and current to be encountered

**LED Indicators**
Tri-color system LED (left side)
- Displays system status, packet transfer, etc.

Two color communication device status (right side)
- Displays status of the communication module. Color sequence depends on the module installed
- When no communication modules are installed only the green LED will come on when 5VDC power is present. This is due to the jumper connection between pins 2 and 7 of the header (#9)

**Battery**
- CR-2032 battery used for memory backup when 5VDC power is lost
- Typically drains less than 2 uA when GEM is powered down
- Life: approximately same as battery shelf life
- Battery replacement should be done while GEM is powered up if accumulated watt-second, counter and time values are to be preserved

**Memory Backup**
- Uses EEPROM to store GEM user settings
- Battery backup holds CPU ram content during power outages. This includes all watt-second, counter and time registers

**Operating Temperature**
Better than: 0 - 40C (TBD)

**Humidity**
5% to 95% non-condensing

**Enclosure Material**
UL94-V0 ABS Plastic

**Dimensions**
9 1/8" X 7 1/8" X 2"

**Weight
(GEM Device Only)**
Between 1.2 and 1.4 pounds depending on installed modules

**FCC Certification**
The GEM complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Depending of the GEM options, the following wireless modules may be installed in the GEM:
- Roving Networks WiFly Module FCC ID: T9J-RN171
- Digi International XBee® Module FCC ID: OUR-XBEE2
- WiFi Module FCC ID: AZYHF-A111

# Channel Assignment Worksheet

| GEM CH # | Load Description | Breaker Number | Breaker Amps | CT Model | 120V | 240V 1-CT | 240V 2-CTs |
|---|---|---|---|---|---|---|---|
| 1 | | | A | | | | |
| 2 | | | A | | | | |
| 3 | | | A | | | | |
| 4 | | | A | | | | |
| 5 | | | A | | | | |
| 6 | | | A | | | | |
| 7 | | | A | | | | |
| 8 | | | A | | | | |
| 9 | | | A | | | | |
| 10 | | | A | | | | |
| 11 | | | A | | | | |
| 12 | | | A | | | | |
| 13 | | | A | | | | |
| 14 | | | A | | | | |
| 15 | | | A | | | | |
| 16 | | | A | | | | |
| 17 | | | A | | | | |
| 18 | | | A | | | | |
| 19 | | | A | | | | |
| 20 | | | A | | | | |
| 21 | | | A | | | | |
| 22 | | | A | | | | |
| 23 | | | A | | | | |
| 24 | | | A | | | | |
| 25 | | | A | | | | |
| 26 | | | A | | | | |
| 27 | | | A | | | | |
| 28 | | | A | | | | |
| 29 | | | A | | | | |
| 30 | | | A | | | | |
| 31 | | | A | | | | |
| 32 | | | A | | | | |